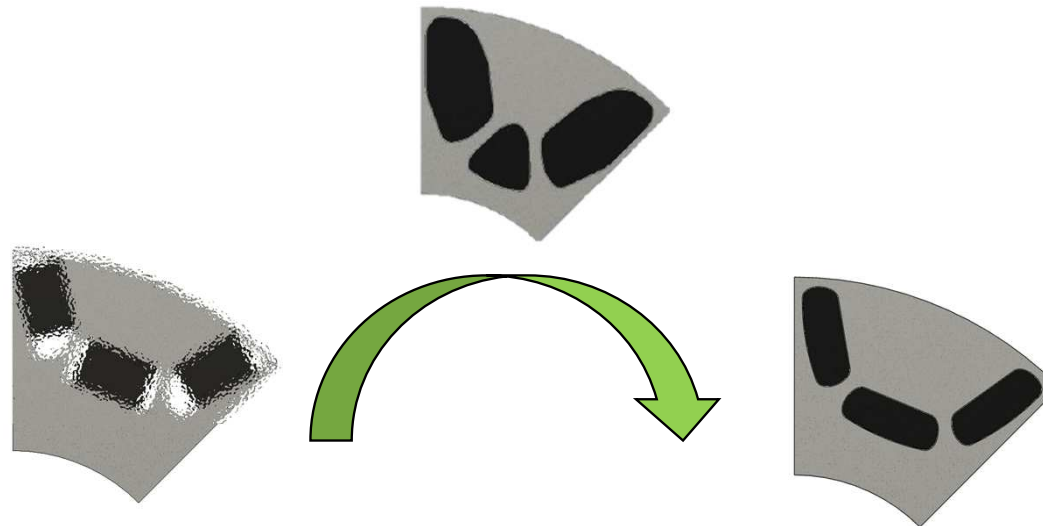

Case study – Racing motor

- Optimization of high-performance motor of German racing motor start-up with Metal Injection Molding (short: MIM) magnets
 - Stator concept: No changes
 - Power electronics: No changes
 - Rotor concept: Freeform modulation of NdFeB permanent magnets with MIM technology
- **Goal:** higher performance and reduced heavy rare earth in magnets for less criticality in supply chain



Case study – Racing motor – Motor A

Starting point:
High performance motor A



Magnet mass 100%

MIM Design Final V3.10: 4 PM

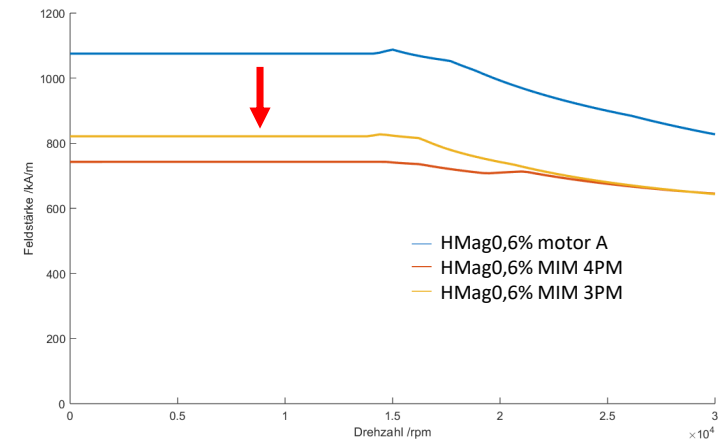
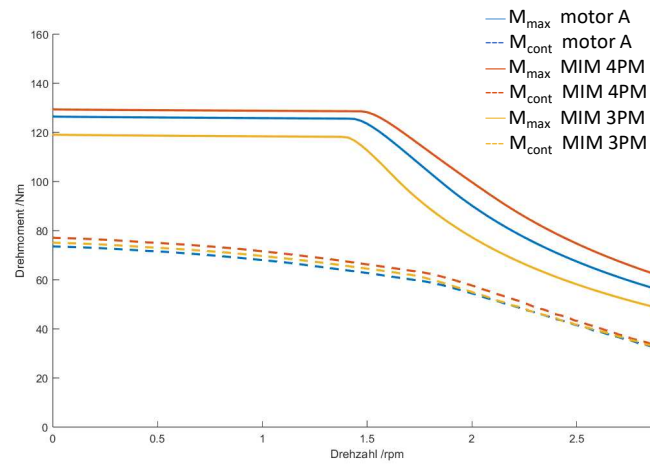


Magnet mass 130%

MIM Design Final V3.10: 3 PM



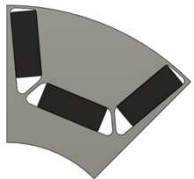
Magnet mass 100%



- High-performance motor was surpassed by MIM Design (4PM)
 - + 2% maximum torque
 - + 4.75% continuous torque
- At same magnet mass the MIM Design (3 PMs) shows
 - + 2% continuous torque
- MIM designs 4PM and 3PM allow + 20 K higher magnet temperature
 - Further increase of continuous torque possible !
 - or
 - Cheaper magnet alloys → less/without Heavy Rare Earths (Dy, Tb) !

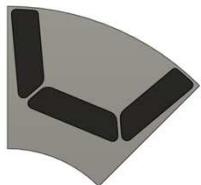
Case study – Racing motor – Motor B

Starting point:
High performance motor B



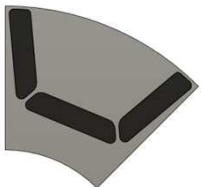
Magnet mass 100%

MIM design „full pocket“

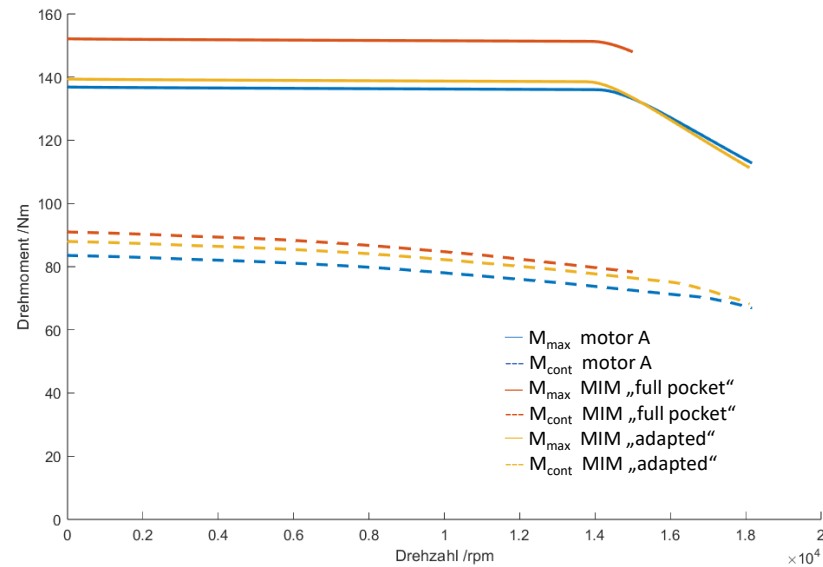


Magnet mass 123%
Reduced speed stability

MIM design „adapted“



Magnet mass 100%
Constant speed stability



- With MIM design „adapted“ (same magnet mass, constant speed stability)
 - + 5.3% continuous torque
 - + 1.8% maximum torque

Case study – Racing motor

Conclusion:

The use of metal injection molding has the following advantages:

1. Higher performance of electric motors
2. Use of heavy rare earths can be reduced
3. Considerable cost advantages compared to press-sintered magnets, as magnets can be manufactured without post-processing operations:
 - a) Eroding is not necessary
 - b) Grinding to produce free-form surfaces is not required
 - c) By eliminating the eroding and grinding operations, the degree of material utilization is significantly higher with metal injection molding
 - d) lower manufacturing costs by reducing the use of heavy rare earths
4. Significantly improved ecological footprint by using recycled magnets or through the reduction of heavy rare earths